STAT [redacted]

Progress Report No. 17

Report Period: 3 July 1967 to 24 July 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No.	SPO 27203
Customer Project No.	
Contract No.	

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	92 as of 23 June 1967*
Percent of Work Completed	92 as of 23 June 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January, 1967, under Redirection of Program Efforts Proposal.

Approved For Release 2002/06/17 : CIA-RDP78B04747A000700020025-6

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

The Psychophysical GEMS tests were initiated on 17 July 1967. Task final report writing continued in a number of areas.

a) Psychophysical GEMS Matrix

The Psychophysical GEMS tests were initiated at the customer's facility. The first week's tests indicate that the matrix array will provide information concerning the usefulness of GEMS and the desirable parameter increment spacing. The tests will include the use of this matrix array to evaluate mission material.

It is anticipated that the testing will be concluded by 3 August 1967.

b) Other Study Tasks

Final reports are being written for a number of study tasks. It is anticipated that most of these will be completed in August.

Work for Next Period

All study efforts will be concluded by end August. Most study final reports also will be completed by that time.

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Manager, Photographic Science Section

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Progress Report No. 16

Report Period: 25 May 1967 to 30 June 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. . . . . .

Contract No. . . . . .

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	87 as of 26 May 1967*
Percent of Work Completed	87 as of 26 May 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective Of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of know quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

During June, the Psychophysical GEMS matrix was fabricated. The majority of the Equal Magnification GEMS Study work was completed; and a final report for this task and the System Parameters Study task are presently being written.

a) Psychophysical GEMS Matrix

The Psychophysical GEMS matrix was completed in June. Arrangements have been made with the customer and [redacted] STAT to initiate the tests on 17 July 1967 at the customer's facility.

The modulation transfer function - exposure matrix array was generated to encompass a suitable performance range of the appropriate camera system as determined from the System Parameters Study. A copy of the Psychophysical GEMS Matrix Data report is enclosed as Appendix A.

b) System Parameters Study

The difficulties encountered in measuring the film granularity have been corrected and new granularity data was obtained. The completion of this task report has been delayed because of the full time involvement of the report engineer on the Psychophysical GEMS Matrix task during June.

c) Equal Magnification GEMS Study

Most of concept phases of the Equal Magnification GEMS approach have been established. The [illegible] universal

film to be used in this approach still has not been determined. Information was received during June on DuPont film type SR102. But, some data concerning the performance aspects of this film type are yet unknown. The data required is forecoming.

Work for Next Period

The Psychophysical GEMS tests will be conducted in July. The tasks reports for the System Parameters Study and Equal Magnification GEMS Study are to be written.

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Manager, Photographic Science Section

Appendix A

Psychophysical GEMS Matrix

Data Report

PSYCHOPHYSICAL GEMS MATRIX DATA REPORT

30 June 1967

General

The enclosed GEMS matrix array is composed of elements varying both in modulation transfer function (MTF) and exposure for three different scenes. The GEMS matrix was fabricated to simulate the appropriate mission material under specific viewing conditions; i.e., when the mission material and GEMS are viewed at 60 and 20 times magnification, respectively. The differences in grain size and scale factor, which would normally exist at these two viewing magnifications, were properly adjusted in the simulation process.

Matrix Element Identification

Each scene matrix element is mounted between glass and identified in two ways. A label containing a random identification number has been placed over a matrix element code number written on the glass plate. The color of the random number labels identifies the three different scenes.

The code number is used to identify particular elements within the matrix array. The first digit (or first two digits in a three-digit code number) indicates the level of MTF where the number (1) represents the highest and the number (10) represents the lowest. The second digit (or third digit in a three-digit code number) indicates the level of exposure where the number (1) represents the minimum exposure and the number (7) represents the maximum exposure.

A listing of these identification numbers is included in this report.

Parameter Specifications

Data sheets defining the objective evaluation of the MTF and exposure parameters for the matrix are included as Figures 1 and 2 of this report. The MTF increments of the GEMS are representative of 10 percent changes in limiting scene ground resolution and depicted by 0.45 modulation response curves. The increment spacings for the seven exposure levels were varied from 0.02 to 0.15 density units to achieve a total exposure shift of 0.38 density units between exposure elements 1 and 7. Reference Figure 2 for the exact value of each increment shift.

The range of MTF's and exposures, as well as the evaluation and reporting of MTF curves at a 0.45 modulation response level, was determined to be most appropriate from the System Parameters Study and most representative of mission material.

The limiting scene ground resolutions reported in Figure 1 correlate with the GEMS directly. When the GEMS are compared with the mission material at the viewing magnifications given above, the limiting scene ground resolutions

are increased by a factor of three. (See table below)

MTF Code Digit(s)	GEMS Scene Ground Resolution(1/mm)	Viewing Factor GEMS Scene Ground Resolution(1/mm)
1	58.7	176.1
2	52.8	158.4
3	47.5	142.5
4	42.8	128.4
5	38.5	115.5
6	34.7	104.1
7	31.2	93.6
8	28.1	84.3
9	25.3	75.9
10	22.8	68.4

MATRIX ELEMENT IDENTIFICATION CHART

(1) Harbor Scene - Pink Labels

(RN / EC: Random Number / Element Code)

RN / EC	RN / EC	RN / EC	RN / EC
00 / 33	29 / 65	61 / 87	89 / 107
03 / 41	30 / 102	62 / 77	90 / 45
04 / 12	31 / 66	64 / 82	91 / 64
05 / 81	32 / 71	65 / 92	92 / 63
06 / 73	33 / 72	66 / 84	93 / 91
07 / 76	35 / 56	67 / 26	94 / 103
08 / 55	36 / 75	68 / 54	95 / 62
09 / 34	37 / 27	69 / 51	96 / 106
11 / 36	38 / 11	71 / 42	97 / 35
12 / 24	39 / 83	73 / 94	99 / 74
14 / 101	45 / 25	76 / 32	
15 / 57	46 / 52	77 / 44	
16 / 14	51 / 13	79 / 96	
17 / 86	53 / 22	80 / 31	
19 / 16	54 / 23	81 / 85	
22 / 43	55 / 95	82 / 37	
24 / 67	56 / 104	84 / 97	
26 / 93	57 / 61	86 / 46	
27 / 53	59 / 17	87 / 105	
28 / 21	60 / 47	88 / 15	

(2) Airfield Scene - Green Labels

(RN / EC: Random Number / Element Code)

RN / EC	RN / EC	RN / EC	RN / EC
00 / 61	29 / 86	61 / 93	89 / 45
03 / 97	30 / 43	62 / 91	90 / 63
04 / 106	31 / 96	64 / 87	91 / 16
05 / 24	32 / 54	65 / 33	92 / 66
06 / 73	33 / 62	66 / 102	93 / 22
07 / 55	35 / 76	67 / 25	94 / 26
08 / 82	36 / 107	68 / 53	95 / 71
09 / 36	37 / 23	69 / 84	96 / 41
11 / 64	38 / 12	71 / 72	97 / 85
12 / 31	39 / 81	73 / 27	99 / 34
14 / 56	45 / 44	76 / 101	
15 / 14	46 / 32	77 / 74	
16 / 92	51 / 105	79 / 46	
17 / 104	53 / 17	80 / 15	
19 / 35	54 / 103	81 / 77	
22 / 21	55 / 95	82 / 75	
24 / 13	56 / 57	84 / 65	
26 / 42	57 / 47	86 / 67	
27 / 11	59 / 83	87 / 94	
28 / 51	60 / 52	88 / 37	

(3) City Scene - White Labels

(RN / EC: Random Number / Element Code)

RN / EC	RN / EC	RN / EC	RN / EC
00 / 75	29 / 21	61 / 82	89 / 62
03 / 56	30 / 15	62 / 34	90 / 53
04 / 95	31 / 26	64 / 61	91 / 52
05 / 106	32 / 44	65 / 37	92 / 12
06 / 54	33 / 27	66 / 65	93 / 51
07 / 101	35 / 87	67 / 36	94 / 11
08 / [illegible]	36 / 16	68 / 17	95 / 105
09 / [illegible]	37 / 63	69 / 47	96 / 45
11 / 96	38 / 14	71 / 103	97 / 84
12 / 85	39 / 32	73 / 73	99 / 43
14 / 42	45 / 35	76 / 92	
15 / 74	46 / 102	77 / 77	
16 / 23	51 / 25	79 / 13	
17 / 107	53 / 67	80 / 22	
19 / 33	54 / 104	81 / 76	
22 / 97	55 / 46	82 / 55	
24 / 83	56 / 24	84 / 66	
26 / 91	57 / 94	86 / 93	
27 / 71	59 / 41	87 / 64	
28 / 57	60 / 86	88 / 72	

(4) Harbor Scene -- Pink Labels

(EC / RN: Element Code / Random Number)

EC / RN	EC / RN	EC / RN	EC / RN
11 / 38	41 / 03	71 / 32	101 / 14
12 / 04	42 / 71	72 / 33	102 / 30
13 / 51	43 / 22	73 / 06	103 / 94
14 / 16	44 / 77	74 / 99	104 / 56
15 / 88	45 / 90	75 / 36	105 / 87
16 / 19	46 / 86	76 / 07	106 / 96
17 / 59	47 / 60	77 / 62	107 / 89
21 / 28	51 / 69	81 / 05	
22 / 53	52 / 46	82 / 64	
23 / 54	53 / 27	83 / 39	
24 / 12	54 / 68	84 / 66	
25 / 45	55 / 08	85 / 81	
26 / 67	56 / 35	86 / 17	
27 / 37	57 / 15	87 / 61	
31 / 80	61 / 57	91 / 93	
32 / 76	62 / 95	92 / 65	
33 / 00	63 / 92	93 / 26	
34 / 09	64 / 91	94 / 73	
35 / 97	65 / 29	95 / 55	
36 / 11	66 / 31	96 / 79	
37 / 82	67 / 24	97 / 84	

(5) Airfield Scene - Green Labels

(EC / RN: Element Code / Random Number)

EC / RN	EC / RN	EC / RN	EC / RN
11 / 27	41 / 96	71 / 95	101 / 76
12 / 38	42 / 26	72 / 71	102 / 66
13 / 24	43 / 30	73 / 06	103 / 54
14 / 15	44 / 45	74 / 77	104 / 17
15 / 80	45 / 89	75 / 82	105 / 51
16 / 91	46 / 79	76 / 35	106 / 04
17 / 53	47 / 57	77 / 81	107 / 36
21 / 22	51 / 28	81 / 39	
22 / 93	52 / 60	82 / 08	
23 / 37	53 / 68	83 / 59	
24 / 05	54 / 32	84 / 69	
25 / 67	55 / 07	85 / 97	
26 / 94	56 / 14	86 / 29	
27 / 73	57 / 56	87 / 64	
31 / 12	61 / 00	91 / 62	
32 / 46	62 / 33	92 / 16	
33 / 65	63 / 90	93 / 61	
34 / 99	64 / 11	94 / 87	
35 / 19	65 / 84	95 / 55	
36 / 09	66 / 92	96 / 31	
37 / 88	67 / 86	97 / 03	

(6) City Scene - White Labels

(EC / RN: Element Code / Random Number)

EC / RN	EC / RN	EC / RN	EC / RN
11 / 94	41 / 59	71 / 27	101 / 07
12 / 92	42 / 14	72 / 88	102 / 46
13 / 79	43 / 99	73 / 73	103 / 71
14 / 38	44 / 32	74 / 15	104 / 54
15 / 30	45 / 96	75 / 00	105 / 95
16 / 36	46 / 55	76 / 81	106 / 05
17 / 68	47 / 69	77 / 77	107 / 17
21 / 29	51 / 93	81 / 08	
22 / 80	52 / 91	82 / 61	
23 / 16	53 / 90	83 / 24	
24 / 56	54 / 06	84 / 97	
25 / 51	55 / 82	85 / 12	
26 / 31	56 / 03	86 / 60	
27 / 33	57 / 28	87 / 35	
31 / 09	61 / 64	91 / 26	
32 / 39	62 / 89	92 / 76	
33 / 19	63 / 37	93 / 86	
34 / 62	64 / 87	94 / 57	
35 / 45	65 / 66	95 / 04	
36 / 67	66 / 84	96 / 11	
37 / 65	67 / 53	97 / 22	

(7) Test Elements

Duplicates of six matrix elements for each of the three scenes are included in the GEMS Matrix for test purposes. The element code numbers are listed below with their corresponding random numbers. The columns of random numbers, from left to right, identify the harbor, airfield, and city scenes, respectively.

EC	Random Numbers		
17	2	6	8
56	5	3	4
62	7	1	7
71	4	9	2
83	1	7	9
95	9	2	3

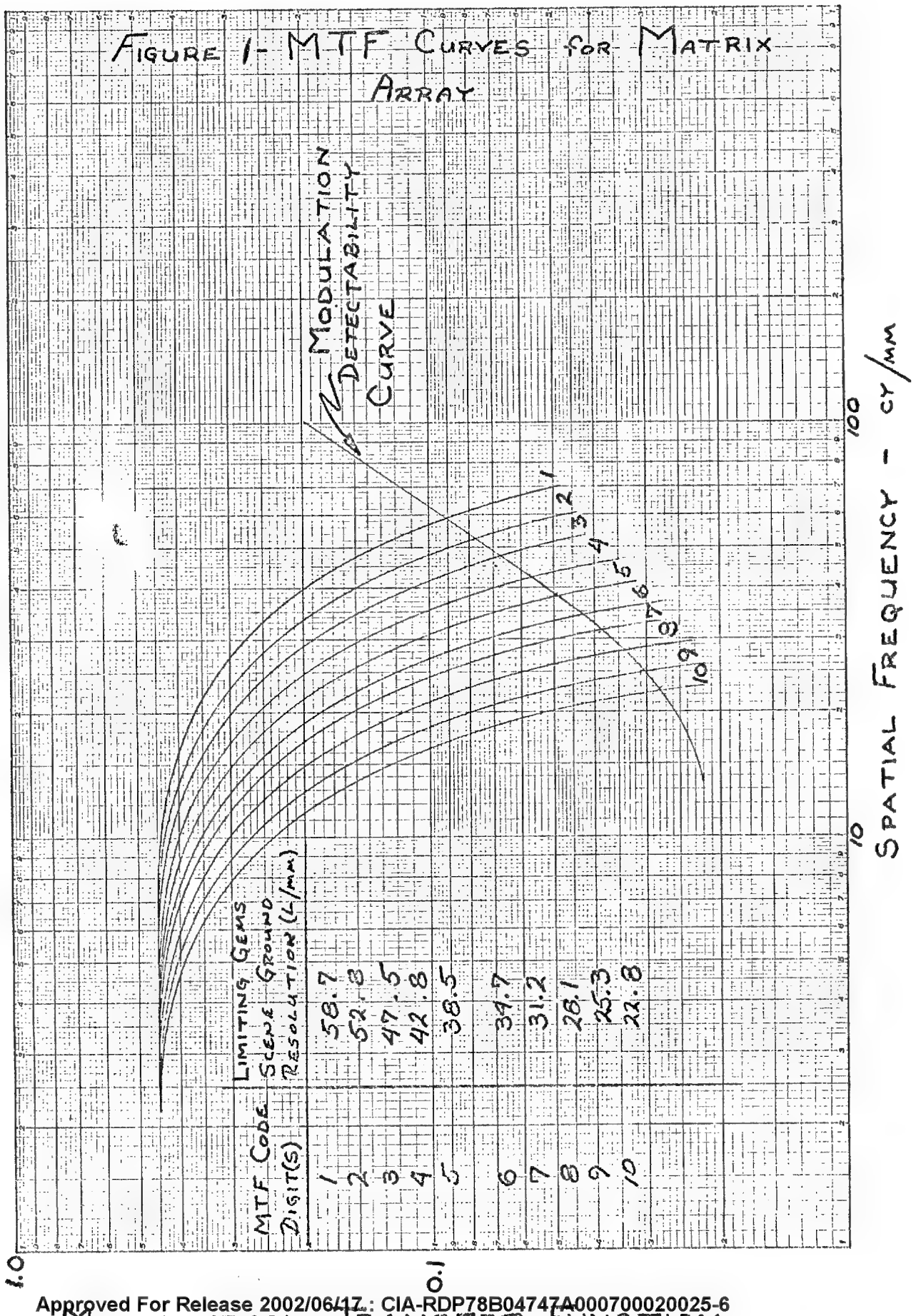

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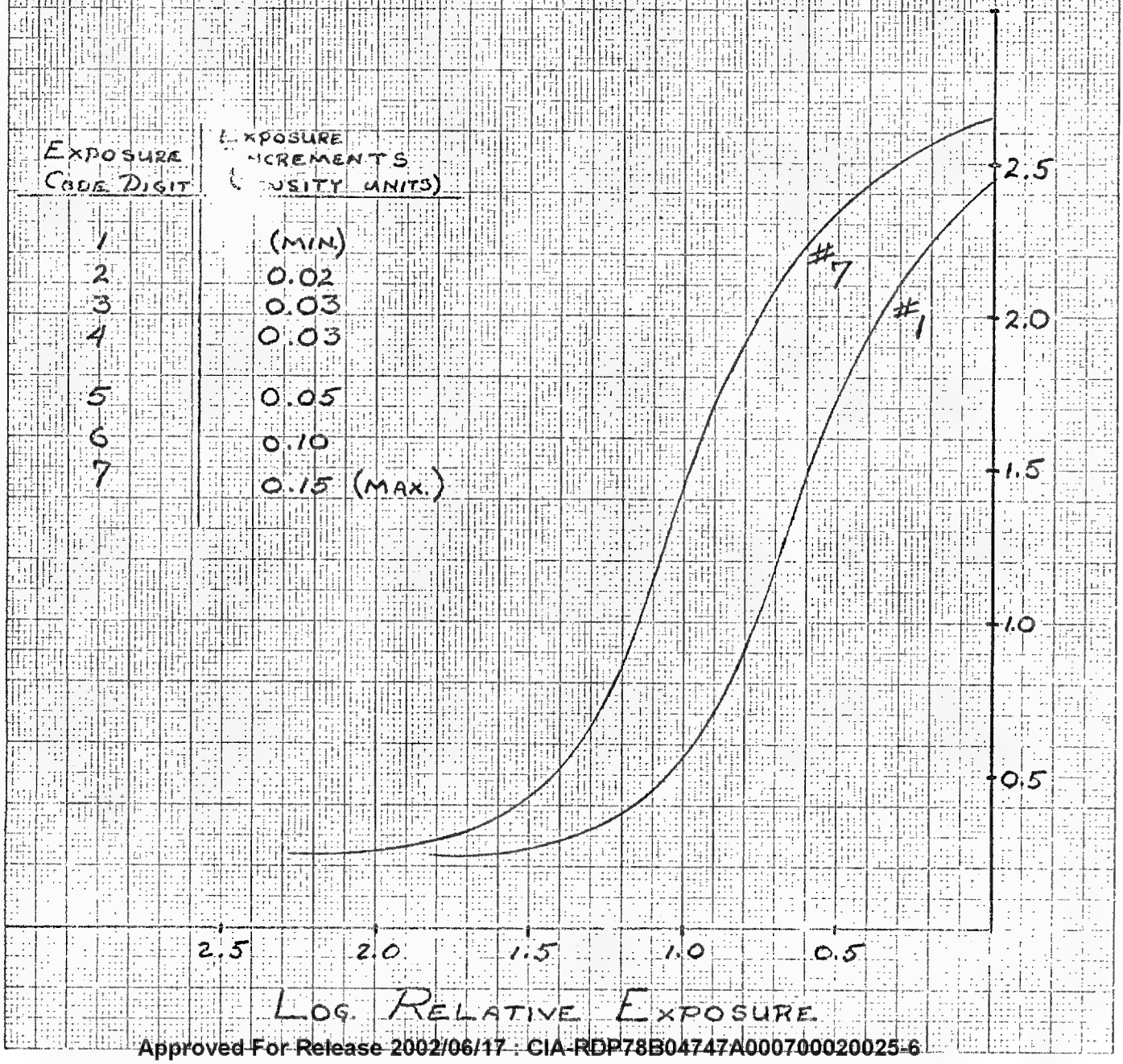
FIGURE 2 - EXPOSURE INCREMENTS for MATRIX ARRAY

EXPOSURE CODE DIGIT	EXPOSURE INCREMENTS (DENSITY UNITS)
1	(MIN.)
2	0.02
3	0.03
4	0.03
5	0.05
6	0.10
7	0.15 (MAX.)



STAT [redacted]

Progress Report No. 15

Report Period: 25 April 1967 to 24 May 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No.	SPO 27203
Customer Project No.	
Contract No.	

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	81 as of 28 April 1967*
Percent of Work Completed	81 as of 28 April 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this object, a number of subtasks are being undertaken, These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

Good progress continued in many areas of the total GEMS Study program. The Psychophysical GEMS matrix is presently in production. The completion date for the System Parameters Study report has slipped because some granularity measurement and computational difficultires were uncovered when analyzing the granularity data. The Pseudo GEMS Viewer concept design study was completed. The Equal Magnification GEMS study effort continued with notable progress.

a) Psychophysical GEMS Matrix

During the past report period, new original negative material was located for use in generating GEMS masters. As well as can be determined, without actually producing a GEM, the new material meets all the sensitometric and resolution requirements. The three scenes are of a harbor, airfield, and an industrial site in the San Diego area.

The GEMS production effort is presently involved with generating the masters. It is anticipated that the GEMS matrix will be completed toward the end of June.

b) System Parameters Study

Some difficulties were uncovered concerning the measurement of granularity. System processed step tablets were used for the measurement procedure. It seems that a few of the steps contain bad Newton rings which were scanned by mistake when obtaining the granularity data. New grain measurements are being made. The final report for this task will be forthcoming in June.

c) Pseudo GEMS Viewer Study

The Pseudo GEMS Viewer study was completed in May. The final report will be sent to the customer within the next few weeks.

d) Equal Magnification GEMS Study

This task is concerned with the aspects of making GEMS at the same scale factor as mission material with adequate scene resolution and contrast. If resolutions in the neighborhood of 150 lines per millimeter are desirable, it will be necessary to incorporate in the GEMS fabrication procedure an optical system with MTF control. This point has been substantiated by a former study that proved that the MTF predictability of the GEMS instrument is Fresnel diffraction limited at approximately 100 lines per millimeter. The present study includes an investigation which will somewhat define the GEMS fabrication optical system.

In order to provide adequate scene contrast and a proper film sensitometric response, it appears ideal to obtain reversal processed original material with a gamma of unity. Since the processed film would be a positive, it would be used directly in the master fabrication stage. The advantage of this approach is that a high resolution positive can be obtained where the exposure input and density output is a fairly linear function for a large exposure range. Negative films with high exposure index speeds, when reversal processed, normally yield non-linear sensitometric data. On the other hand, most good reversal films are slow speed films and not suitable for recording flight aerial imagery. Reversal materials are presently being investigated to determine if a suitable film is available on the market. A DuPont duplicating film, SR102, appears to possess the desired characteristics; but insufficient data exists, at the moment, to know if this film type will meet the requirements.

Work for Next Period

The June activities will include preparing the Psychophysical GEMS matrix, delivery of the Pseudo GEMS Viewer and System Parameters study reports, and completion of the Equal Magnification GEMS study activities.

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Progress Report No. 14

Report Period: 27 March 1967 to 24 April 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. . . . . .

Contract No. . . . . .

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	79 as of 24 March 1967*
Percent of Work Completed	79 as of 24 March 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

Good progress was made in many areas of the total GEMS Study program. Most of the Psychophysical GEMS matrix preliminary work was completed. The System Parameters Study proceeded approximately as scheduled; objective measurements were made on mission material and the data reduction effort completed. The Pseudo GEMS Viewer concept design study established conceptual approaches for control of all parameters to be simulated. The Equal Magnification GEMS Study effort was initiated during April.

a) Psychophysical GEMS Matrix

Further experiments were conducted on the visual impression of film type 3400 grain size. The intent of this task is to find a film type that will yield the same visual impression of grain size when viewed at 20 times magnification as film type 3404 when viewed at 60 times magnification. Our recent findings indicated that film type 3400 grain is too coarse for an adequate simulation.

Several other film types were examined during the past month. Film type SO 206 was found to yield a very realistic impression of the grain size desired when exposed and processed under the conditions to be used for generating the Psychophysical GEMS. SO 206 grain is slightly coarser at low densities and slightly finer at high densities than 3404. However, the mid-range of densities yields a very realistic simulation; and only after a very intense examination at these mid-range densities, can one detect slight differences in size. It is anticipated that SO 206 will be adequate for the Psychophysical GEMS Matrix.

It is to be mentioned that SO 206 yields an impression of a more uniform density over a large area than 3404. Due to the nature of the size imagery to be simulated, it is not felt that the above would create any problems during psychophysical testing.

An attempt was made to generate photographs of SO 206 and 3404 film grain under the optical viewing conditions to be used during testing. These attempts failed because of long exposure, sample illumination, and vibration problems.

The preliminary Psychophysical GEMS matrix work continued more or less as scheduled. The image quality measurements were not performed on the original negatives to be used when generating GEMS masters. Two of the original negative scenes intended for use were lent to another facility; and of this report writing, have not been returned.

The problems associated with the aerial image density patch measurement device have been resolved, and the device is ready for use in obtaining accurate GEMS master sensitometric data. The copy system, employed to generate masters, presently is being assembled and aligned.

b) Refinement of Techniques

A three-day visit was made to the [redacted] STAT
STAT [redacted] in March. Material from various missions was scanned on their microdensitometer to obtain measures of several system parameters for the System Parameters Study.

In summary, six, two inch, scene area scans were obtained for different types of terrain, with a 1 by 80 micron slit. The various types of scene content included mountainous terrain, air field structure, city structure, cultivated field terrain, and industrial structure. The data from these six area scans was used to define the parameters of exposure and contrast. In addition, three independent scans were made of ten edges. The edge gradients
STAT were processed through the [redacted] edge-gradient analysis program to obtain a measure of system image quality.

Specific details concerning the measurements and the results is forth-coming in the System Parameters Study final report. Objective measure-
STAT ments were made at [redacted] to define the properties of tonal scale, density neutrality, and granularity.

c) Pseudo GEMS Viewer Study

In Progress Report No. 13, design aspects for control of exposure and contrast were presented. The design aspects for these two parameters have been investigated in greater detail. The result of this investigation has been a reconfirmation of the design approach.

Six methods were proposed for control of modulation transfer function. Further examination of GEMS Viewer optical design has resulted in establishing a seventh method which appears most suitable. It is proposed that the eight levels of modulation transfer function be controlled by the introduction of zero diopter lenses below the de-rotation prism compensator (see optical schematic in GEMS Viewer study report). The advantages of this scheme include:

(1) precise control of both MTF shape and spatial frequency extent in incremental steps.

(2) little or no effect on illumination level.

(3) relatively easy to manufacture.

(4) provides both a flexible and repeatable means of control.

The Pseudo GEMS Viewer optical magnification range presently is under reconsideration. It was established for the GEMS Viewer that a magnification range of 6 to 60 times, in two steps, would be provided. However, it is believed that material generally is not evaluated with less than 20 times magnification. It has been proposed to the customer that the Pseudo GEMS Viewer magnification range may be most adequately handled in one step with magnifications from 15 to 60 times. The advantage of this consideration is a substantial cost reduction in manufacturing the optical system of the instrument. If magnifications below the 15 times serve a necessary role, it is recommended that this proposed change be dropped.

d) Equal Magnification GEMS Study

This study was initiated during April. The primary intent of the study is to establish a means of generating simulated photographs at the appropriate scale factor of mission material. Sensitometric considerations and resolution problems hindered our attempts to generate a proper Psychophysical GEMS matrix some months ago.

The problems related to generating the Psychophysical GEMS matrix have been defined. As a result of the problem study, it became apparent that a new approach would have to be established for generating the desired simulated photographs. The investigation is to include the consideration of silver and non-silver systems, conventional and unconventional processing, and possible optical approaches.

Work for Next Period

The Psychophysical GEMS matrix work will be continued. The System Parameters Study final report will be delivered to the customer during May. The Pseudo GEMS Viewer Study will be completed. Work will be continued on the Equal Magnification GEMS Study.

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Manager, Photographic Science Section

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Progress Report No. 13

Report Period: 27 February 1967 to 24 March 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. . . . . .

Contract No. . . . . .

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	78 as of 24 February 1967*
Percent of Work Completed	78 as of 24 February 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

A number of visits were made to the customer's facility in February and March. During these visits, material was selected for use in obtaining objective measures of system parameter performance characteristics. The Psychophysical GEMS matrix preparational work was continued. The Pseudo GEMS Breadboard concept design study was initiated during March.

a) Psychophysical GEMS Matrix

The 3400 grain size comparison tests are presently being conducted. If the 3400 grain size yields a visual impression of 3404 grain when viewed at the appropriate magnification factor, work will commence on generating the Psychophysical GEMS matrix during April. Some of the initial work involving making masters has begun. A number of potential scenes have been selected for use. The final choice of the scenes is dependent upon the image quality measurements to be made in April. These scenes were selected from original negative material that was processed to a gamma of 1.0.

b) Refinement of Techniques

Original negative material was selected for the System Parameters Study on 28 February. Arrangements have been made for performing various microdensitometer measurements on this selected material at the [redacted] STAT
STAT [redacted] Facility on 27 March. Density and edge gradient measurements will be made for the purpose of defining the operational system parameters of exposure, scene contrast, and modulation transfer function.

Four, fully processed, system step tablets were recently received. These step tablets will be used to obtain objective measures of granularity, density neutrality, and tonal scale. If no unforeseeable problems develop when gathering data, the System Parameters Study will be concluded during April.

c) Pseudo GEMS Viewer Study

The Pseudo GEMS Viewer Study was initiated by investigating the means of controlling the parameters of contrast, exposure, and modulation transfer function. Consideration has been given to the redesign of the GEMS Viewer optical system to accomplish the above.

It appears feasible to control exposure by cascaded filter wheels, a relatively simple means of control offering flexibility, accuracy, and convenience. The cascade filter wheels will be used in conjunction with a beam splitter to control contrast. (A beam splitter is employed to introduce flare light). In an effort to reduce the degradations introduced by this beam splitter, as experienced during the Pseudo GEMS breadboard study, it appears possible to place the beam splitter in the de-rotational prism compensator region. Degradations will be less since this is essentially a collimated region.

At present, six methods have been proposed for the control of the modulation transfer function. The methods of control being considered are:

1. varying the lens aperture
2. defocusing
3. using a deformable liquid or plastic cell
4. combining various positive and negative low diopter lenses
5. using aberration plates
6. using variable-transmission masks

The entire GEMS Viewer optical system still is being examined for the optimum manner in which to introduce controlled changes of modulation transfer function.

d) Completed Tasks

STAT [redacted] visited with the customer on 20 March. One objective of his visit was to discuss the progress of the GEMS Study program; in specific, the results of the Alternate Technique and Pseudo GEMS tasks.

At the customer conference, a general opinion expressed was that technical advancements have been made on both tasks; and that the Pseudo GEMS approach appears quite feasible.

Work for Next Period

Initial preparations for producing the Psychophysical GEMS matrix will continue. It may be possible to produce new GEMS masters by end-April. STAT The System Parameters study should be completed during the next month. The Pseudo GEMS Viewer study will continue.

[redacted]
Photographic Evaluation Group

Approved For Release 2002/06/17 : CIA-RDP78B04747A000700020025-6

[redacted] STAT

Progress Report No. 12

Report Period: 25 January 1967 to 24 February 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. . . . . .

Contract No. . . . . .

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	29 September 1967**
Percent of Total Funds Expended	75 as of 27 January 1967*
Percent of Work Completed	75 as of 27 January 1967*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Status of Overall Project

Work on the redefined study program tasks commenced during January. Notable progress was made in the areas of the alternate procedure for preparing the Psychophysical GEMS matrix and the System Parameters study. Both the Pseudo GEMS breadboard and Alternate GEMS Technique reports were sent to the customer. The preparation of the prior efforts Refinement of Techniques report has been delayed due to extensive work being performed in other task areas.

a) Psychophysical GEMS Matrix

During the past month, the initial objectives of analytically and experimentally proving the feasibility of the alternate procedure for making GEMS was initiated. Several film types were examined for potential similarities of 3404 grain size when viewed at a factor of three lower magnification.

Film type 3400 has shown good promise as a candidate film for use in generating the Psychophysical GEMS. The film has been checked for sensitometric and modulation transfer function characteristics. The experimentally determined film properties support the analytical results previously obtained. The grain size of 3400 is visually comparable to 3404 when viewed at a factor of three difference in magnification. Additional comparisons of grain size are being made at different density levels and at the appropriate microscope magnification factors.

b) Refinement of Techniques

The System Parameters study was initiated in January. A report was written to describe the manner of obtaining data with which to define the system parameters.

During February, a visit was made to the customer's facility. The purpose of this visit was to gather data appropriate to the parameters study. A check of the system performance reports and any other source of data indicated that the desired data is non-existing. The remainder of the visit was devoted to defining the type data required. Another visit to the customer's facility will be made on 28 February. On this visit, material will be selected for measurement of the various parameters.

An aerial image read-out device was breadboarded a few months back in order to read the effective lens image plane density values of a copy camera setup. Experimentation with this device was continued. The former problems, hindering repeatable measurements, were found to be created by the instability of the photomultiplier tube. With the instability problem corrected, the experimentation has been resumed.

c) Alternate Technique

This task was completed during February with the delivery of the task final report.

d) Pseudo GEMS Breadboard

The Pseudo GEMS breadboard experiments were completed in January. A final report on the experiments was submitted to the customer in February. The Pseudo GEMS viewer concept design study will commence in March.

Work For Next Period

The 3400 film type grain study will be completed in March. The initial preparations for producing the Psychophysical GEMS will begin. It is anticipated that most of the System Parameters study data will be collected in March. However, the progress of this activity is dependent on approval to have measurements made at another facility, and the success of this task will be dependent upon the working order of the evaluation equipment. The Pseudo GEMS viewer concept design study will be initiated by examining what is needed to control the alteration of various photographic parameters.

STAT

[redacted]

Photographic Evaluation Group

[redacted] STAT

Progress Report No. 11

Report Period: 29 November 1966 to 24 January 1967

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. . . . . .

Contract No. . . . . .

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Schedules Completion Date	29 September 1967**
Percent of Total Funds Expended	74 as of 23 December 1966*
Percent of Work Completed	74 as of 23 December 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

** New completion date established as of January 1967 under Redirection of Program Efforts Proposal.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the fabrication of a Pseudo GEMS breadboard.

Program Redirection of Effort

In Progress Report No. 10, attention was directed to existing technical problems associated with the generated Psychophysical GEMS matrix. A sensitometric study of the problems has indicated that the desired GEMS parameters of resolution and contrast cannot be obtained by employing 2.3 gamma, original negative material in the simulation process.

In the 2.3 gamma sensitometric study report, submitted to the customer during the month of December, it was indicated that the simulated photographs would be markedly improved by employing original negative material possessing a processing gamma of unity. However, it is believed that unity gamma material would not produce adequate simulations if it is obtained under previous flight conditions.

The outcome of these problems has been a recommendation to redirect the program efforts as formally presented to the customer on 16 January. At this time, it is obvious that our earlier course of action would not permit one to accomplish the desired program goals. In addition, more recent knowledge of image simulation technology indicates that the Pseudo GEMS technique may be a more favorable approach to the subjective evaluation of image quality than simulated GEMS photographs.

It is not possible to state that either one of the two simulation techniques will yield the program objectives more readily than the other. Therefore, it has been recommended that the program activities be directed toward a parallel effort in both the photographic GEMS and Pseudo GEMS technical areas. In the redirected program, successful completion of the contract is constituted by performing a Psychophysical GEMS study with a matrix prepared by an alternate GEMS process, resolving the technical problems associated with generating GEMS photographs at equal magnification, developing a Pseudo GEMS Viewer design concept, and preparing a final report which will relate the simulation approach most acceptable to the objective of finalizing an image evaluation technique.

A description of the current program efforts is covered in greater detail in the GEMS study redirection of efforts report.

Status of Overall Project

During the last two months, the efforts of the study program have been redefined. Work on other program tasks, not affected by the simulation problems, continued as outlined in the last monthly report. Final testing of the alternate technique is nearing completion, and the Pseudo GEMS breadboard experiments have been performed.

a) Psychophysical GEMS Matrix

An alternate procedure for preparing a Psychophysical GEMS matrix was proposed as one area of redirection. The initial objectives of preparing a new matrix are to analytically and experimentally prove the feasibility of the alternate procedure for making GEMS. The parameters of modulation transfer function, sensitometry, and grain size, as related to the procedure, are being verified.

b) Refinement of Techniques

This task has been enlarged to include the System Parameters Study, Equal Magnification GEMS Study, and the Flight Program Specification activity. At end-January, the System Parameters Study will be initiated. The purpose of this subtask is to objectively define the mission material parameters of MTF, contrast, exposure, granularity, and sensitometry. The objective measures will be used to specify the GEMS parameters.

A report covering the previous work performed under this task is being prepared. The preparation of this report has been delayed because of program problems during the past two months.

c) Alternate Technique

The experimental work of this task has been completed. Some analytical work remains to be done before a final task report can be written on this task. It is anticipated that the task report will be delivered to the customer during the month of February.

d) Pseudo GEMS Breadboard

The Pseudo GEMS Breadboard equipment was fabricated by end-December. Experiments were performed with the equipment to establish the feasibility of this GEMS approach. The experiments were highly successful. A task report is currently being prepared for submission to the customer by end-January. Photographs of the degraded scene will be included in the report.

Work for Next Period

Most of the analytical and experimental alternate procedure verification work will be performed by end-February. As previously reported, the System Parameters Study will be initiated by end-January; and a report, covering prior Refinement of Techniques efforts will be prepared. The Alternate Technique task work will be completed in January and the task report submitted during February. The Pseudo GEMS breadboard report will be submitted by end-January.

STAT

Rec'd 6 Dec.

[redacted] STAT

Progress Report No. 10

Report Period: 25 October 1966 to 28 November 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	30 June 1967
Percent of Total Funds Expended	65 as of 28 October 1966*
Percent of Work Completed	65 as of 28 October 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the preparation of GEMS sets in large numbers.

Status of Overall Project

The Psychophysical GEMS study and the Matrix GEMS activities are temporarily haulted at this time due to technical difficulties. Work is continuing on the refinement techniques. Final testing of the alternate techniques equipment is proceeding as scheduled.

a) Psychophysical Testing

[redacted] STAT visited the customer's facility on 7 November for the purpose of conducting the Psychophysical GEMS study. An initial visual examination of the matrix array indicated that the increment spacing of modulation transfer function, MTF, was hardly evident. Since the matrix elements of MTF were not as desired, the tests were postponed.

On 21 November, [redacted] STAT visited the customer to discuss the problems associated with the improper MTF spacing. The problem mainly stems from poor resolution masters. The poor resolution is a function of the photographic processing required to obtain a positive master transparency with a cascaded gamma of 1.0 from an ON with a gamma of 2.3. The MTF of the ON is also questionable since the sensitometric data used for the MTF determinations had to be assumed. The resolution problem was further complexed by performing negative GEMS, MTF predictions based on the scene's maximum modulation.

The justification for processing the positive master transparency to a cascaded gamma of 1.0 was formally presented in the first image simulation study final report. Under the conditions described, the MTF of the GEMS instrument mask can be convolved with the MTF of the master without introducing nonlinearities. The GEMS contrast and resolution can be improved to a great degree by employing ON material with a gamma of 1.0 when generating masters. On the other hand, the GEMS contrast and resolution can be improved when employing ON material with a gamma greater than 1.0 if a computer program can be developed to take into account the nonlinear response of the film in the MTF prediction process. At the 21 November customer conference, [redacted] STAT agreed to investigate the feasibility of predicting and controlling MTF simulation for a nonlinear photographic system.

A new psychophysical GEMS matrix will be generated after the current resolution problem is resolved.

b) Refinement of Techniques

In last month's progress report, it was reported that we were investigating commercially available high resolution lenses. We have been unsuccessful in locating a lens with the characteristics previously described.

The technique for measuring aerial image, copy camera, sensitometric density patches has been moderately successful. A photo-multiplier tube device is presently being breadboarded. A photo-conductivity cell was experimented with, but the cell was found to be inadequate for the light intensity range and too sensitive to environmental temperature changes.

The simulated contrast study effort was continued during the past month. The study data currently is being analyzed and a report should be completed in the month of December. One of the problems associated with the accuracy of this simulation technique is the control and/or repeatability of the GEMS instrument light source. General type photographic flash tube units are repeatable to only 20% of their watt-second output and ordinarily influenced by environmental conditions. This 20% watt-second variability produces exposure shifts equivalent to 0.06 density units. A light source that permits an equivalent 0.01 density unit repeatability has been located.

c) Alternate Technique

The new lens system which replaced the inadequate initial lens system does not yield the resolution performance anticipated. The lens MTF curve, as measured by edge gradient analysis, indicates a 0.2 modulation at 100 lines per millimeter. Although this performance falls short of our expectations, it has been decided to proceed with this lens system and design apertures for MTF modifications below 100 lines per millimeter.

d) GEMS Matrix

The commencement date of the GEMS Matrix array has been postponed until the Psychophysical GEMS Study is completed. Some preliminary work associated with automating the GEMS production process will continue.

e) Pseudo GEMS Viewer

The scope of the present contract was changed to include the bread-boarding of a Pseudo GEMS Viewer. Some preliminary planning was completed during the two weeks since the contract extension was received.

Work For Next Period

With investigating the feasibility of controlling MTF simulations for a nonlinear photographic system and re-generating the psychophysical GEMS, it is anticipated that the program will be extended beyond the June 1967 completion date. It is a little premature, at this time, to specify the new completion date.

During the next report period, the feasibility of controlling MTF simulations for a nonlinear photographic system will be investigated; and an experiment demonstrating this control will be performed if the technique can be made operational in a short period of time. A report on the refinement of techniques will be written. Preliminary work associated with automating the GEMS production process will continue. The final tests of the alternate GEMS bread-board equipment and preparation of the technical report should be nearing completion.

The Pseudo GEMS Viewer activity will increase during the next month. Photographic GEMS material will be prepared. Material for breadboarding the viewer will be placed on order or gathered. Finalizing of the instrumentation conceptional design will be completed.

STAT

[redacted]

Photographic Evaluation Group

[redacted] STAT

Rec'd 28 Oct 66

Progress Report No. 9

Report Period: 25 September 1966 to 24 October 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	30 June 1967
Percent of Total Funds Expended	60 as of 23 September 1966*
Percent of Work Completed	60 as of 23 September 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the preparation of GEMS sets in large numbers.

Status of Overall Project

All subtask activities are proceeding as scheduled. The psychophysical GEMS production was completed by mid-October; final testing of the alternate technique equipment began this week; and existing simulation techniques are being improved to permit both the efficient production of the matrix GEMS and more precise simulations of mission photography.

a) Psychophysical Testing

STAT The production of the psychophysical GEMS set was completed and shipped to [redacted] on 17 October. The set was produced to the photographic parameters described in previous Progress Reports. [redacted] will be STAT studying the GEMS and designing psychophysical experiments until the 31 October test period. The experiments will be conducted at the customer's facility during the month of November.

The split-field microscope will not be sent to the customer's facility. The microscope was found to be inadequate for comparing imagery because of a light source color difference which exists between the two microscope illuminators.

b) Refinement of Existing Techniques

The current effort on this subtask is directed toward the refinement of existing techniques and the development of new techniques necessary to accomplish the production of 1024 matrix GEMS. The breadboard copy camera system, used to generate masters from original negatives, is being improved in order to achieve higher resolution masters. We are presently investigating commercially available lenses with a 500 to 600 line per millimeter (aerial image) uniform resolution capabilities over a 15 by 7.5 millimeter image format area at approximately a 10 times reduction factor. Such a lens will make it possible to generate 200 + line per millimeter masters on type S0243 film.

A technique for measuring aerial image, copy camera, sensitometric density patches is being developed in order to permit more accurate MTF evaluations of the masters. Such a technique will provide a means of gather EGA sensitometric data compensated for the lens' $\cos^4$ illumination fall-off.

An analysis was performed to ascertain the qualities that an original negative must possess in order to properly simulate the parameters of the mission material by the GEMS technique. The key factor associated with the original negative is its processing. If it is desired to maintain both an adequate scene density range and high resolution in the simulation process, it is essential that the original negative be photographically processed to a gamma of unity.

The justification for the unity gamma processing can be described best by explaining the inadequacies of GEMS generated from higher gamma originals. The simulation procedure requires that a positive master transparency be generated with a cascaded gamma of unity. For an original negative with a gamma of 2.3, it is therefore necessary to process the master transparency to a gamma of 0.43. In the master reduction process, the 2.8 density range of the negative material is compressed to 0.84 density units. When these positive master transparencies are used to generate negative GEM PHOTOGRAPHS with a gamma of 2.3, the maximum density range that can be achieved is 1.45 density units. Under normal processing conditions for a gamma of 2.3 and with the proper exposure or scene illuminance, the mission material has a 2.6 to 2.8 density range capability.

When using a high gamma original negative, nothing can be done to match the density range of the GEM PHOTOGRAPHS with the mission material without detrimentally influencing some other photographic parameter in the simulation procedure. The low gamma processing of the master transparencies also limits the resolution capabilities of the GEMS.

Ideally, negative material, processed to a gamma of 1.0 and possessing a maximum density of 1.5 to 1.6, should be used when generating the master transparencies. An official request was submitted to [redacted] on 13 October for such negative material obtained from the system designated as "B" Material along with a sensitometric step tablet. (All other parameters should be the same as for the material obtained previously.) The material is required by mid-December, at the latest, if it is to be used in generating the matrix GEMS. STAT

A current study is being performed to validate a new means of calculating the pre-exposure and image exposure times for the atmospheric haze or contrast simulation technique. The major problem associated with the prediction procedure has been the effect of Recriprocity Law Failure. The effect of RLF was eliminated by adapting a strobotac type flash unit as a GEMS instrument light source. The flash unit is capable of making exposures at 1/1000 of a second.

c) Alternate Technique

Preliminary testing of the initial lens system selected indicated resolution on film to be well below the goal of 200 cycles/mm. Another lens system was substituted and the goal achieved. The next step, the determination of the

system MTF by edge gradient analysis, is in progress at this writing.

d) GEMS Matrix

The production of the GEMS Matrix array is scheduled to commence in January 1967. Preliminary work, such as the ordering of supplies and the fabrication of jig fixtures, has already begun. The photographic parameters of the matrix will be established in concert with the customer after the results of the psychophysical study have been reviewed.

Work for Next Period

During the next report period, most of the psychophysical study experiments will have been conducted at the customer's facility. The activity on the refinement of techniques, as related to the production of the GEMS matrix, and the preliminary work associated with the GEMS production effort will continue. Performance of the present alternate GEMS optical system will be optimized, and final testing using variable transmittance and rotating variable area apertures should begin.

STAT

[redacted]

Photographic Evaluation Group

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[redacted] STAT

Progress Report No. 8

Report Period: 25 August 1966 to 24 September 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No . . . . . SPO 27203

Customer Project No 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract	[redacted] STAT
Scheduled Completion Date	30 June 1967
Percent of Total Funds Expended	51 as of 26 August 1966*
Percent of Work Completed	51 as of 26 August 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the preparation of GEMS sets in large numbers.

Status of Overall Project

The GEMS Study Program has proceeded on the schedule submitted in last month's letter report. Many of the steps in the psychophysical subtask have been completed. The present rate of progress indicates that the starting date of 31 October for the psychophysical testing can be achieved without difficulty.

a) Psychophysical Testing

In early September, production of the psychophysical GEMS was initiated. The customer's facility was visited on 8 September for the purpose of comparing an exposure series of GEM PHOTOGRAPHS with mission photography. On 9 September, a meeting was held with [redacted] to discuss the psychophysical tests, and other details pertaining to conducting these tests.

STAT

The present status and rate of progress indicates that the starting date of 31 October for the psychophysical testing can be achieved. It is estimated that the tests will require four of the customer's personnel part time over a four week period. Three image evaluation personnel will be required to contribute fifty hours each during the test interval. A fourth individual is needed to administer the tests for a three week period at forty hours per week. The tests will be directed toward determining the increment spacing for exposure and MTF, and determining the accuracy and repeatability with which GEMS can be used. The psychophysical tests will be conducted without the use of mission material.

It is the intent of [redacted] to forward a split-field microscope to the customer's facility during the month of October. However, this microscope may prove to be inadequate for the tests because it does not possess a zoom capability. A dual stage, zoom featured microscope exists at the customer's facility; it would be appreciated if this microscope would be made available in the event that it is needed.

STAT

The parameters of the psychophysical GEMS matrix array will consist of 10 levels of MTF at 8% increments of spatial frequency, 7 levels of exposure - 6 equal increments spaced at 0.75 units of opacity and one exposure level at half the increment interval mid-range of the exposure series, and three different types of scene content. Six duplicate elements for each scene matrix array will be generated for testing purposes. The GEM PHOTOGRAPHS will be mounted between glass and identified with random numbers

b) Refinement of Existing Techniques

The new printing procedure has been incorporated in the breadboard GEMS instrument and the film fixture has proven to be quite advantageous in the production of the psychophysical GEMS. The unexposed film-master transparency separation is established and maintained parallel to within 0.0003 inches. A xenon light source recently was installed in the GEMS instrument. GEMS are being produced with 1/1000 second exposure times and the use of variable transmission masks. This short exposure time has eliminated the problems previously encountered with Reciprocity Law Failure.

c) Alternate Technique

The breadboard model of the alternate GEM technique was aligned. Preliminary tests were conducted on the unit with no aperture. These tests are still in progress and are directed towards obtaining maximum performance from the optical system. The mask specification computer program was verified and determined to operate satisfactorily. No final mask shapes were specified since the MTF of the breadboard optical system is required as an input and is not yet available Also a procedure was examined for producing variable transmittance apertures by an evaporation method. This was investigated since such an aperture could be used in the system if the rotational mechanism produces undesirable vibration effects.

d) GEMS Viewer

STAT On 13 September, [redacted] was given an informal design and cost, summary presentation on the viewer. The viewer design study final report was submitted to the customer during the week ending 16 September. Delivery of this final report constitutes subtask completion.

Work for Next Period

During the next report period, most of the psychophysical GEMS production activity will be completed. An effort will be made to finalize the psychophysical test period details and to co-ordinate the activities of the three facilities by mid-October. Work will be continued on the Refinement of GEMS procedures. Preliminary tests on the alternate equipment will be completed, and the final testing will be initiated.

STAT

[redacted]

Photographic Evaluation Group

[redacted] STAT

Progress Report No. 7

Report Period: 25 July 1966 to 24 August 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer Project No. 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract Price	[redacted] STAT
Scheduled Completion Date	30 June 1967
Percent of Total Funds Expended	42 as of 29 July 1966*
Percent of Work Completed	42 as of 29 July 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

Objective of Project

The principal objective of this project is to determine how well the image quality of mission photography can be assessed by means of GEMS. In order to accomplish this objective, psychophysical tests shall be performed wherein photographic images of known quality (GEMS) are compared to mission photography. In fulfillment of this objective, a number of subtasks are being undertaken. These subtasks consist of the refinement of existing GEMS making techniques, the study of alternate techniques, the study of GEMS viewing equipment, and the preparation of GEMS sets in large numbers.

Status of Overall Project

On 18 August 66, the GEMS Study Program was reviewed with the customer. A progress report on all program subtasks was presented. A closer look at the two subtasks, refinement of existing GEMS techniques and the psychophysical GEMS study, indicates that both of these activities can be completed by end December. If the final GEMS matrix subtask commences in early January, it is anticipated that the total program will be completed in the 18 month performance period.

a) Psychophysical Testing

The original photographic imagery from which the psychophysical GEMS set is to be prepared was received on 8 August 1966. Three of five scenes were employed to generate master transparencies.

As discussed with the customer, the psychophysical study schedule was rearranged to allow subtask completion by end December. This subtask schedule of activities is shown in Figure 1. The schedule requires that the customer furnish three (3) image evaluation personnel, starting 31 October 1966 for a 6 to 8 week test period. Further information concerning the rate of effort required of these three individuals will be furnished to the customer by mid-September and also reported in Progress Report No. 8.

It has been decided that the scene content would consist of a harbor, an airfield, and an industrial site. In addition to the three scenes, there will be 5 increments of exposure and 10 increments of modulation transfer function.

b) Refinement of Existing Techniques

An analytical analysis is being performed on the factors influencing the control and predictability of the modulation transfer function and contrast (haze) simulation techniques. The greatest effort for this subtask is scheduled to commence by mid-September and complete by end November.

A new printing procedure is being incorporated in the breadboard GEMS instrument. Unexposed film will be held flat by a vacuum platen, and the separation between the unexposed film and master transparencies will be controlled to a high degree of accuracy. The printing problems that result for the use of liquid will be eliminated since the separation now will be an air gap.

c) Alternate Technique

The breadboard model of the Alternate GEMS Making Equipment was completely fabricated. (This system employs a rotating variable - area mask in the aperture plane.) Also, a computer program was written to allow the computer to specify the mask shape required for the desired modulation transfer function results.

d) GEMS Viewer

The viewer design study was completed. To confirm the validity of the design approach, a scale drawing of the instrument with additional layouts was made. The optical design was prepared; it provided continuous magnification of 6 to 60 times in two steps. Electronic schematics were prepared for all electronic functions. In the design, consideration was given to human engineering aspects to minimize operator fatigue.

Work for Next Period

During the next report period, production of the psychophysical GEMS will begin. Some activity on the technique refinement analyses will be continued. The Alternate GEMS Equipment will be aligned and preliminary tests will be conducted. The mask specification computer program will be verified and used to specify desired mask shapes. The fabrication of masks to these specific shapes will commence. It also is anticipated that the GEMS Viewer final report will be completed by 8 September 1966. The total program schedule has been reviewed and revised. The revised subtask schedule is illustrated in Figure 2.

STAT

PSYCHOPHYSICAL GEMS STUDY

1. Generate Masters & Evaluate
2. Engineering
3. Generate Matrix Elements & Evaluate (150 GEMS)
4. STAT a) [ ] Design Tests
   b) [ ] Testing & Report (3 image evaluation personnel)
5. P-E Data Analysis & Report

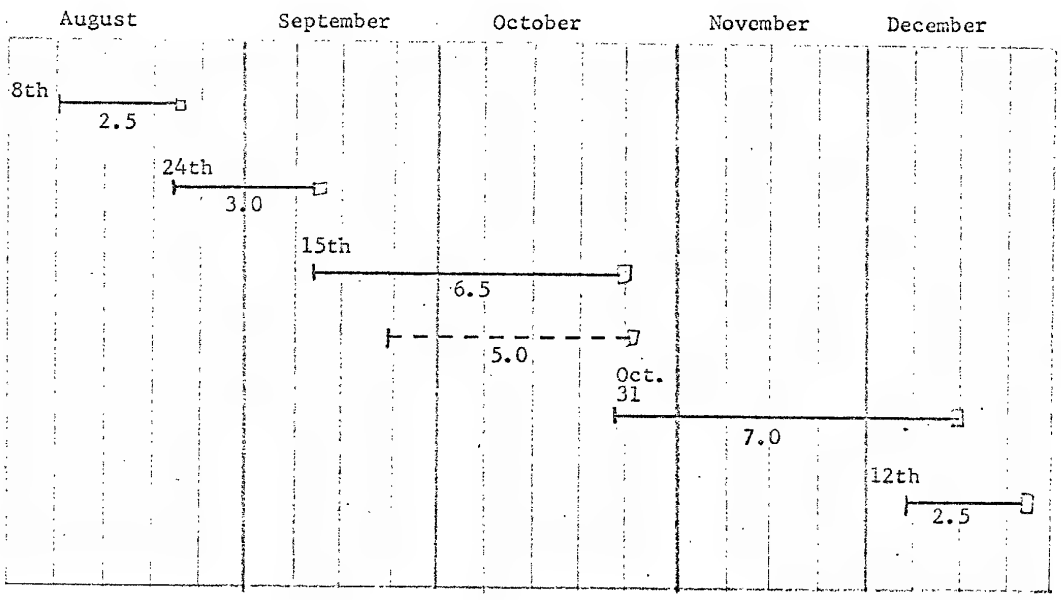

Figure 1

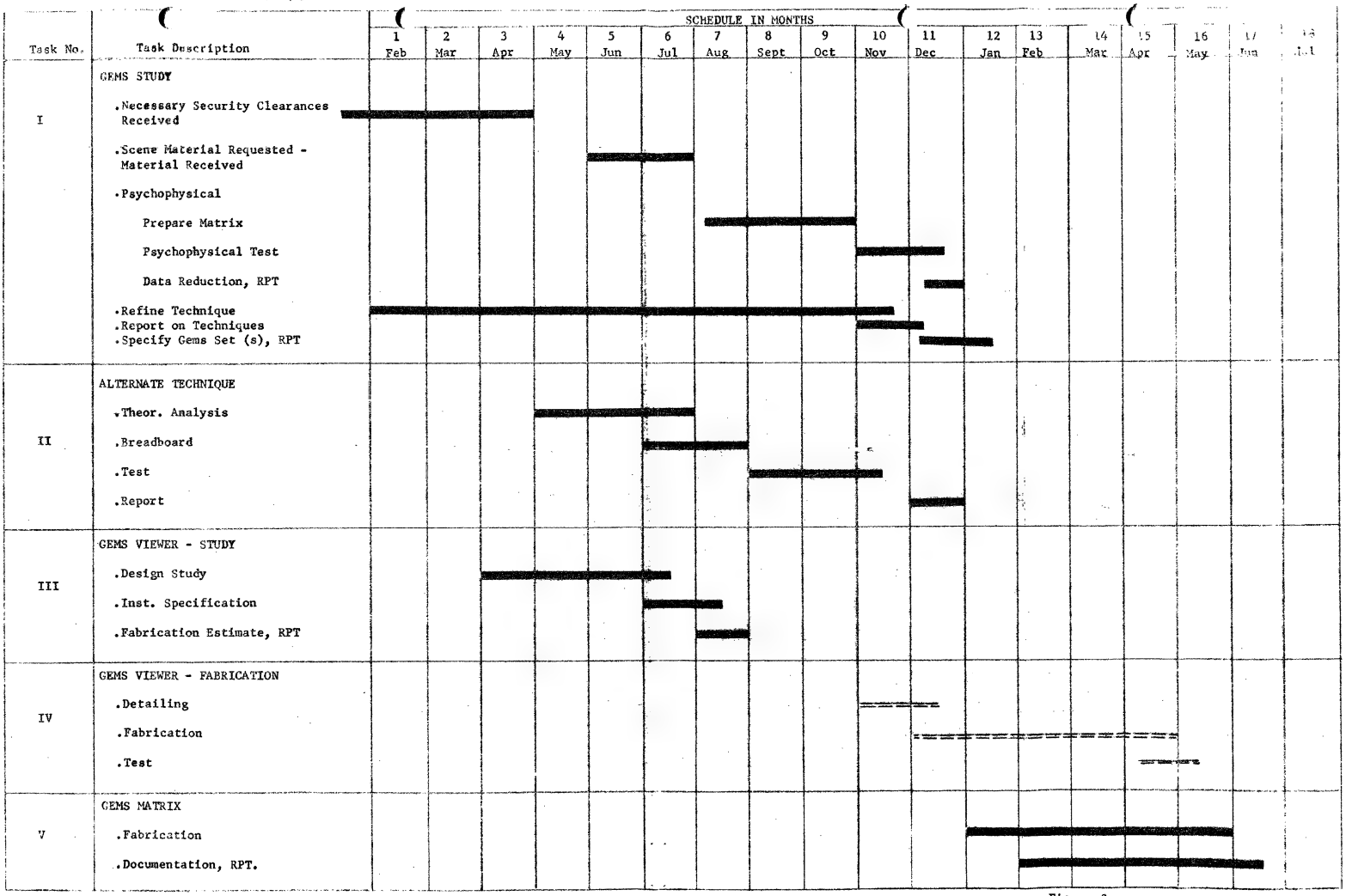

Figure 2

[redacted] STAT

Progress Report No. 6

Report Period: 25 June 1966 to 24 July 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer's Project No. 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract Price	[redacted] STAT
Scheduled Completion Date	30 June 1967
Percent of Total Funds Expended	34.0 as of 25 June 1966*
Percent of Work Completed	34.0 as of 25 June 1966*

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* Report of expenditures and work completion lags technical progress report by approximately three weeks.

Status of Overall Project

At the end of this sixth month (1/3 of the program schedule), two of the four major subtasks are within cost and schedule. These subtasks are the development of an alternate Gems Technique and the Gems viewer study. The subtasks that are behind schedule are the refinement of existing Gem techniques and the psychophysical Gems study. Accelerated effort in both of these areas is required in order to complete the total program within the 18 month performance period. Progress on the individual subtasks and the problem of overall schedule are discussed herein.

a) Psychophysical Testing

The original photographic imagery from which the psychophysical Gems set is to be prepared was reviewed at the customer's facility on 1 July. Five scenes were selected for delivery to Perkin-Elmer but have not as yet been received.

The delay in obtaining suitable source material has made it necessary to reschedule the psychophysical task on the basis of receiving the original negatives by 1 August 66. A new schedule has been developed up through the completion of the psychophysical Gems set. The schedule is predicated on some alterations to the original approach and will require coordination with both customer and subcontractor. A joint meeting on this problem during the next report period would be advisable and shall be attempted.

b) Refinement of Existing Techniques

An accelerated effort is planned on this task in order to complete it prior to the preparation of the Gem matrices which are required as the last item of the contract. The results of this effort and the success of the alternate technique (see para. c) will determine whether or not all the deliverable Gems can be completed by contract end date of 30 June 67. This task is being rescheduled. Clearly, this task and the completion of the psychophysical testing will delay the start of work on the final Gem set (1200 Gem elements). The revised schedule on the activity will be available for review during the August performance period.

In the technical areas the most notable progress has been in the evaluation of Edge Gradient techniques as applied to the monitoring of Gem characteristics. The linear image motion experiment described earlier has been extended to a spatial frequency limit of approximately 100 cycles per millimeter. The results are shown in figures 1, 2, and 3. Figures 1 and 2 demonstrate the precision of edge gradient analysis up to 175 cycles per millimeter. In each instance the best three of four MTF determination are given. The spread in these experimental observations is remarkably small. It may be concluded from these data that the edge gradient technique that we use is precise enough for application to the evaluation of the Gems to be made under this program. The accuracy of this technique is demonstrated in Figure 3.

The quotion of the MTF determinations represented in Figures 1 and 2 should be the transfer function of the linear image motion introduced experimentally. The fit of this experimental data to the theoretically predictable linear image motion MTF is shown in Figure 3. The excellent fit of theoretical and experimental points is a conclusive demonstration of accuracy up to spatial frequencies of approximately 100 cycles per millimeter. This result cannot be extended to higher spatial frequencies without a significant refinement in the experimental apparatus.

c) Alternate Technique

The development of the alternate Gems making technique is on schedule. The theoretical evaluation is being completed and the breadboard unit is in fabrication.

d) Gems Viewer

The design study of the Gems Viewer shall be completed during the August performance period. A report on this task will be submitted during that interval. During the current report period, the design of the viewer's optical system has been advanced based on an optical arrangement that would provide continuous magnification from 5x to 75x in two increments.

Work for Next Period

During the next report period the fabrication of Gems for psychophysical testing will be started, the optical breadboard for the alternate technique will be completed, and the design study for the Gems viewer will be finished. Also a review of schedules will be made with the customer wherein particular attention will be given to the psychophysical study.

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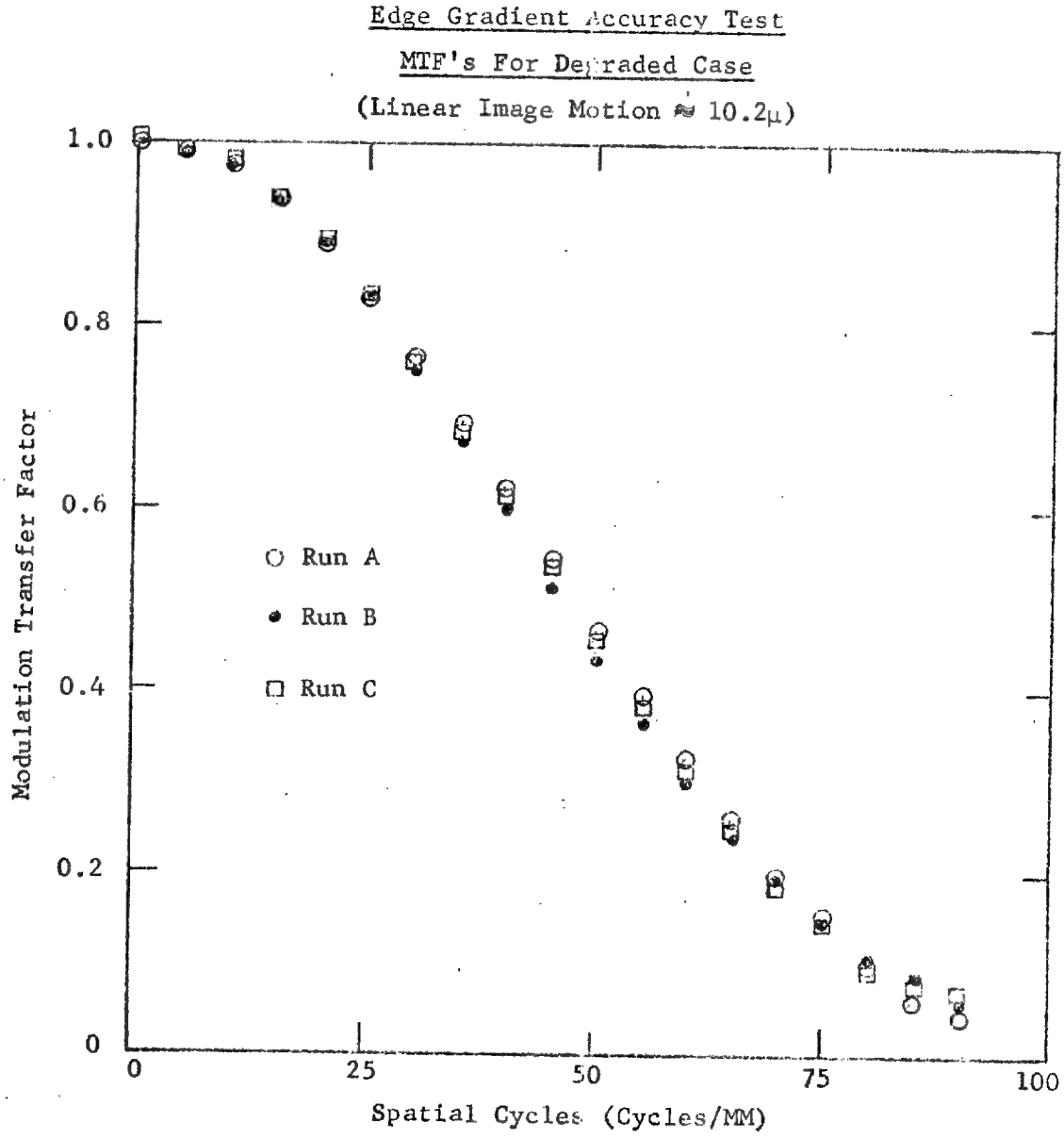

Figure 1 MTF with Linear Image Motion

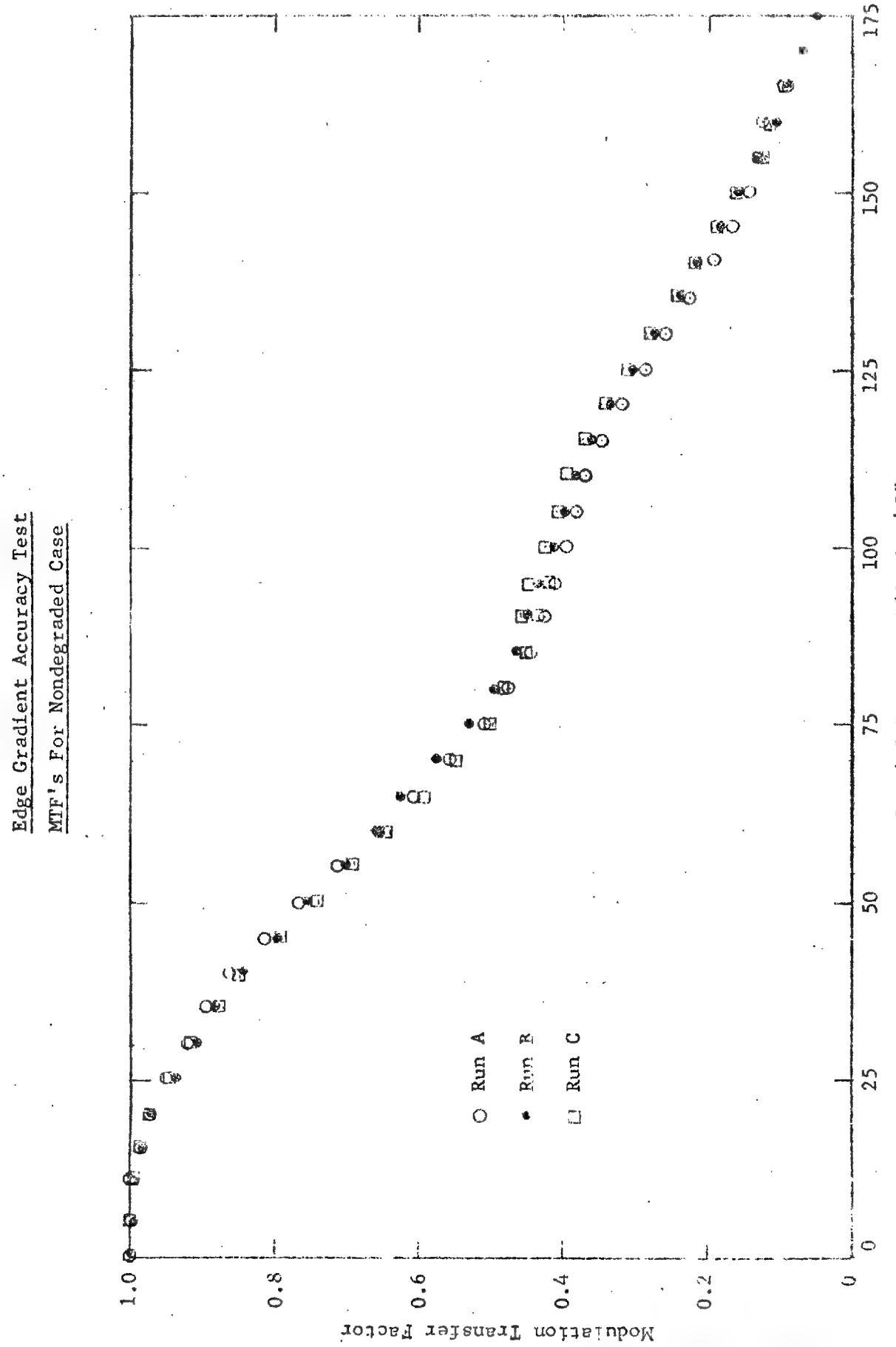

Figure 2 MTF Without Linear Image Motion

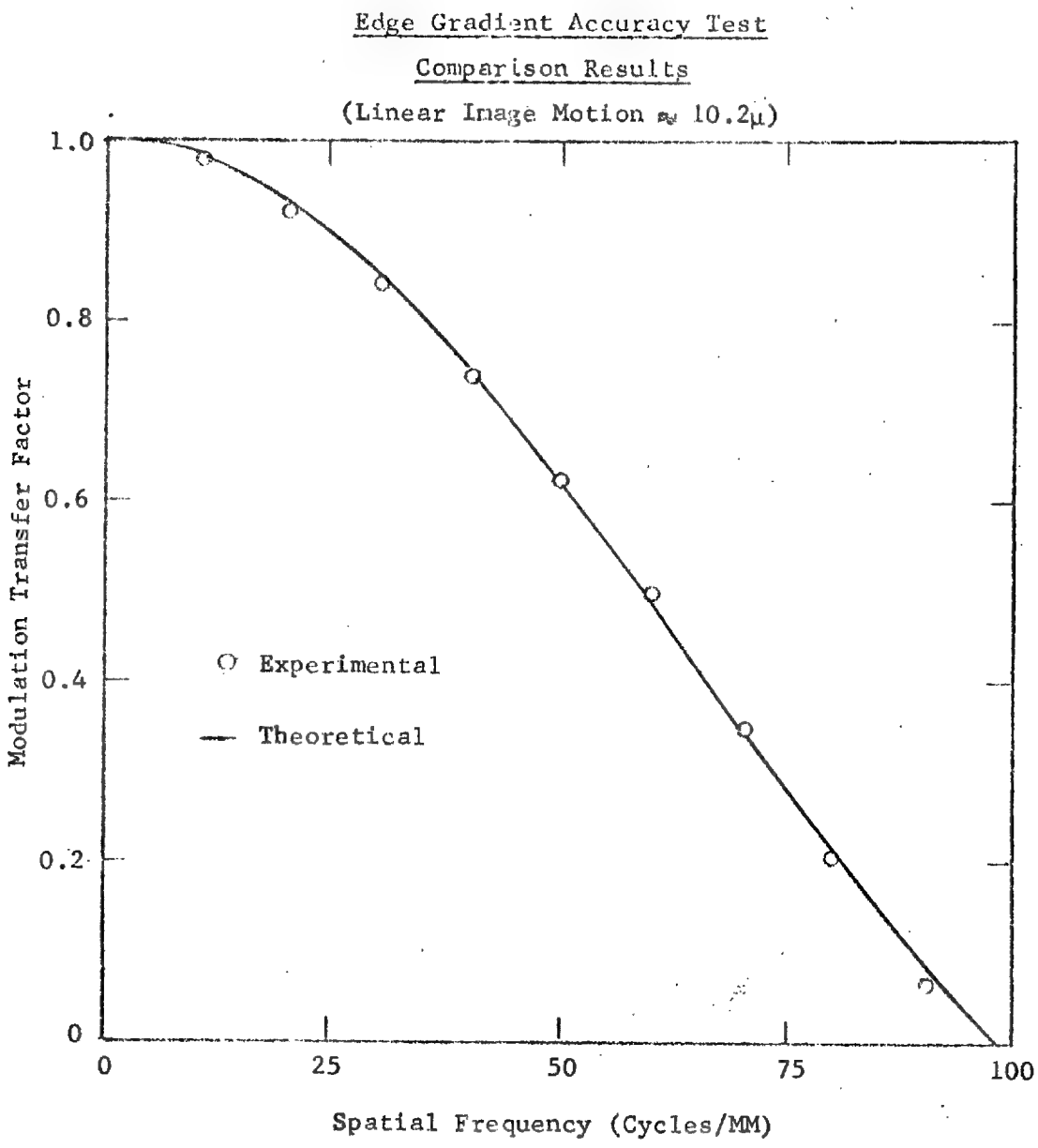

Figure 3 Comparison of Analytical and Experimental Curves

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Progress Report No. 5

Report Period: 30 May 1966 to 24 June 1966

Project Title: Gems Development (continuation)

PROJECT IDENTIFICATION

Contractor's Project No. . . . . SPO 27203

Customer's Project No. 99740-6

Contract No. . . . . [redacted] STAT

FISCAL DATA

Type of Contract	CPFF
Total Contract Price	[redacted] STAT
Scheduled Completion Date	30 June 1966
Percent of Total Funds Expended	29.9 as of 27 May 1966*
Percent of Work Completed	29.9 as of 27 May 1966

* Report of expenditures lags technical progress report by approximately three weeks.

Status of Overall Project

Toward the end of this fifth month, two physicists were added to the program one to assist in the development of the alternate techniques and a second to be concerned with refinements in the existing Gem fabrication methods. In the coming month additional personnel engaged in other Gems programs will be able to contribute a larger share of their time and in the next month adequate personnel will be available to accelerate this Gems program. Detail developments on the various subtasks are given below.

a) Psychophysical Testing

The original photographic imagery from which the psychophysical Gems set is to be made was not obtained from the customer as had been anticipated. This material is now being collected by the customer in the expectation that it will be reviewed by [redacted] at the customer's facility during the week of 4 July. STAT

b) Refinement of Existing Techniques

The linear image motion test of the edge gradient technique has been extended to higher spatial frequencies. This has been done without any elaborate refinements in the experimental set up in the hope that adequate accuracy tests can be made with a minimum expenditure of time. Results of these tests will be reported during the next period.

c) Alternate Technique

The development of an optical breadboard for testing an alternate Gems making technique is being considered. The approach that has been selected as well considerations given to alternate methods are described in an appendix to this report.

d) Gems Viewer

The straightfoward aspects of the Gems viewer have been committed to a design layout. This layout includes the concept of the roll film transport, viewing table, split microscope and carousel type Gems holder.

Work for the Next Period

Work on all phases of the program will continue during the next period. In that time, particular emphasis will be given the breadboard arrangement for studying the alternate Gems technique, and

acquisition of the original imagery necessary for the production of the phychophysical Gems set. Also, receipt of a split field microscope is anticipated.

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MONTHLY LETTER REPORT NO. 5

APPENDIX I

INVESTIGATION OF ALTERNATE MTF

SIMULTATION PROCEDURES

INVESTIGATION OF ALTERNATE MTF SIMULATION PROCEDURES

by

STAT

Summary:

It is required to determine a procedure for the simulation of aerial photographs at high spatial frequencies. Various methods for achieving specified modulation transfer functions have been investigated. A modified copy system employing a rotating area mask was determined most suitable.

Introduction:

In the initial Gems Study, unconventional printing techniques have been used for the simulation of aerial photographs. These simulation techniques permit the production of photographic images with specified modulation transfer functions (MTF's), granularity, contrast, exposure, scale factor and scene content. These procedures have been used successfully in the spatial frequency range of 0 to 100 cycles per millimeter. It is desired to extend capabilities to a higher spatial frequency range; therefore, an investigation into possible procedures for producing images with specified MTF's was conducted.

Four possible methods for producing specified MTF's are:

1. the modified printing technique,
2. the modified copy system,
3. the spatial filtering technique, and
4. the scanning-reconstruction system.

Each of these methods has been examined.

Modified Printing Technique:

The modified printing technique is presently employed in our facility. A suitable source spread function is formed by the use of a rotating mask. An exposure is made with the original transparency and the film separated by a glass spacer. The MTF of the exposure is given by $M_E(k) = M_S(m_1 k) \cdot M_C(m_2 k) \cdot M_F(k)$ where:

k is the spatial frequency in the film plane,

$m_1 = v/u,$

$m_2 = (u+v)/u,$

u is the distance between the source plane and the transparency plane,

v is the distance between the transparency plane and the film plane,

$M_S(k')$ is the MTF of the mask in the source plane,

$M_C(k')$ is the MTF of the transparency in the transparency plane, and

$M_F(k)$ is the MTF of the film used in the exposure.

The use of the factors m_1 and m_2 translates the values of the MTF's from their original planes to the plane of the film.

This spacer contact printing technique allows the control of the MTF of the exposure. However, the condition for Fresnel diffraction exists since the transparency and film plane are separated by a finite distance. To minimize diffraction effects, it is necessary to minimize the distance v and, therefore, minimize the distance u since the value $m_1 = v/u$ is fixed by the desired MTF values. However, it is impossible to minimize these distances (v+u) as much as desirable since a finite spacer and reasonable geometry must be employed. A recent study demonstrated the technique to be fairly accurate for the 0 to 100 cycle per millimeter region. However, at higher spatial frequencies serious alterations are produced by Fresnel diffraction.

Modified Copy System:

The modified copy technique employs a lens system to create an image of the transparency. The control of the resulting MTF might be accomplished by:

1. accurately employing defocussing,
2. use of controlled image motion,
3. use of special lens stops.

A photographic system is quite sensitive to focus errors. It appears unlikely that the adjustable distances can be controlled accurately enough to make a "defocus" system feasible. In addition, such a system produces MTF's of a certain type with little control of general shape.

The use of controlled image motion — or controlled film motion — is possible for one directional MTF degradation. However, to produce a symmetrical MTF would be an almost impossible mechanical task. Controlled image motion is not a feasible MTF simulation procedure except to simulate one-dimensional image motion, if desirable.

The use of special lens stops to produce specified MTF's is based on a knowledge of diffraction-limited MTF's. The normal stop employed in a lens system is shown in Figure 1a; it cuts off all light which is located at a distance greater than the radius of the stop while passing the central light. The use of such fixed stops for MTF simulation would produce MTF's of the form given by:

$$m(k) = \frac{2}{\pi}\left(\cos^{-1}\frac{k}{k_L} - \frac{k}{k_L}\sqrt{1-\left(\frac{k}{k_L}\right)^2}\right)$$

where: k is the spatial frequency in the image plane,

k_L is the limiting spatial frequency given by $k_L = 1/N\lambda$,

N is the aperture ratio, and

λ is the wavelength.

This is unacceptable since it produces one type of MTF whereas a variety of shapes are desirable.

To control the shape of the transfer function, it is necessary to employ stops which have transmittance that varies with the distance from the center of the stop. This type of variable transmittance stop is shown in Figure 1b. The resultant MTF produced in the film plane by the stop-lens system will be given by the autocorrelation function of the pupil function.

Mathematically this is:

$$m(k_x,k_y) = \int_{-\infty}^{\infty}\int g(B,\gamma)\, g^*\left((B-\lambda k_x),(\gamma-\lambda k_y)\right) dB d\gamma$$

where: k_x and k_y are the spatial frequencies in the image plane for the x and y directions respectively.

B and γ are the coordinates of the aperture expressed in angular terms as seen from the image plane.

$g(B,\gamma)$ is the pupil function -- the complex amplitude distribution over the aperture.

λ is the wavelength of light.

Since the pupil function can be controlled in a variable stop system, the method of employing variable stops is feasible. It is the best technique for a modified copy system.

There are three alternate methods to produce a variable stop system:

1. closing diaphram system,
2. variable transmittance mask,
3. rotating variable area mask.

It is theoretically possible to employ a diaphram system which closes at controlled rates, thus producing specified MTF's. However, the production of various different MTF's would require different non-linear closing rates. To be continually changing the diaphram closing speeds while maintaining accuracy is impractical.

The use of variable, transmittance masks is also impractical. The simulation of different MTF's would require the creation of different transmittance masks. The creation of new variable transmittance masks is a time consuming procedure making this approach not feasible.

The use of a rotating stop results in a variable transmittance pupil function while employing a variable area mask. Therefore, the simulation of different MTF's requires the fabrication of different variable area masks. The creation of these masks is not difficult. The best method for a modified copy system is, therefore, the use of a rotating area mask to act as a variable transmittance stop. Such a method is practical and could be used for the simulation of photographs.

Spatial Filtering Arrangement

It is possible to employ spatial filtering to control the final MTF of an image. Figure 2 shows the conventional spatial filtering arrangement. Two identical lenses are placed one between the transparency and filter-plane and the second between the filter plane and image plane with all separations being equal to the focal length of the lenses. A transmittance filter placed in the filter plane results in reducing the spatial frequency components of the final image.

This approach is similar to the modified copy system since it also must employ a variable transmittance "stop". All arguments applied to this previous case relating the various methods of obtaining a variable transmittance stop would also apply.

The main difference between the two methods is that spatial filtering implies a coherent optical system. Coherent optical imaging can present problems from interference patterns. In addition, for a spatial filtering system, the placement of the rotating mask is more critical then for the modified optical system.

Scanning-Reconstruction System

A scanning-reconstruction system would employ the following steps:

1. The original transparency is scanned with a spot scanner and the transmittance values are recorded in digitized form.

2. The frequency content of the scene is altered in any desired manner by computational means.

3. The image would then be reconstructed by a flying spot print out technique.

This type of procedure would require elaborate equipment to produce accurate results. It is felt that simplier, less expensive equipment can be used to accomplish the desired results.

Conclusions

The modified printing technique arrangement has been found inadequate for high spatial frequencies. The best arrangement for the modified copy system — a rotating area mask used as an optical stop-is sound in principle. The spatial filtering technique requires somewhat more complex equipment and techniques than the modified copy system. The scanning-reconstruction system appears to be too elaborate a procedure for use in photographic simulation. The modified copy system as described earlier appears the most sensible approach for the simulation of high spatial frequency photographs. A calculation has shown the approximate size of a typical mask to be reasonable.

The operation of a modified copy system is shown in Figure 3. The initial arrangement is for a one-for-one copy system. The transparency is imaged on the film by a lens and the exposure is made. A rotating area mask-variable transmittance stop-near the lens plane produces the desired MTF of the image. The proper mask configuration is determined by a computer. (The transparency, film and desired image MTF's are supplied as inputs and the proper mask dimensions are obtained as outputs.)

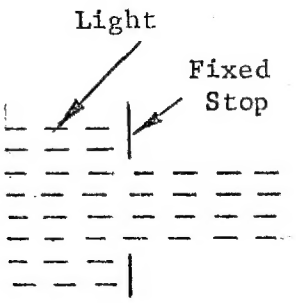

Figure 1a. Fixed Stop

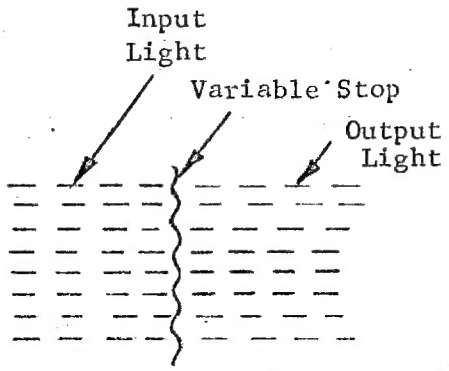

Figure 1b. Variable Stop

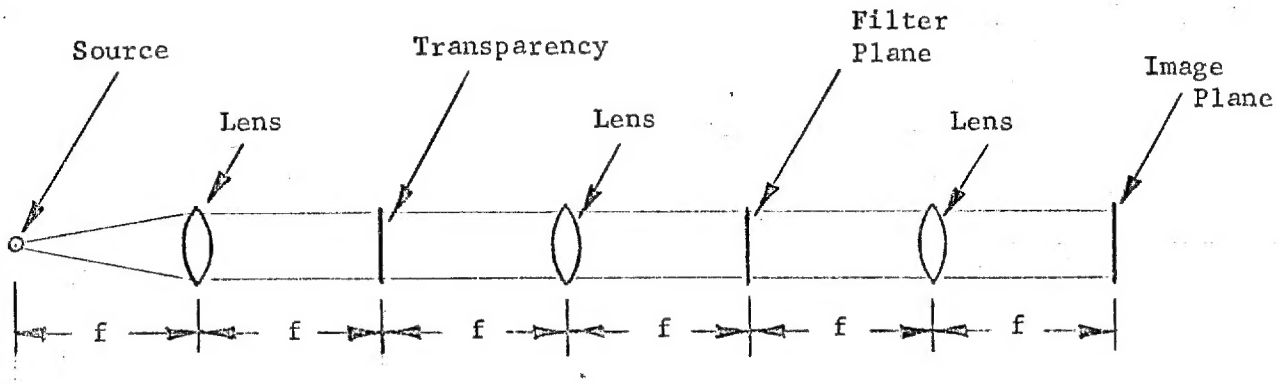

Figure 2. Spatial Filtering

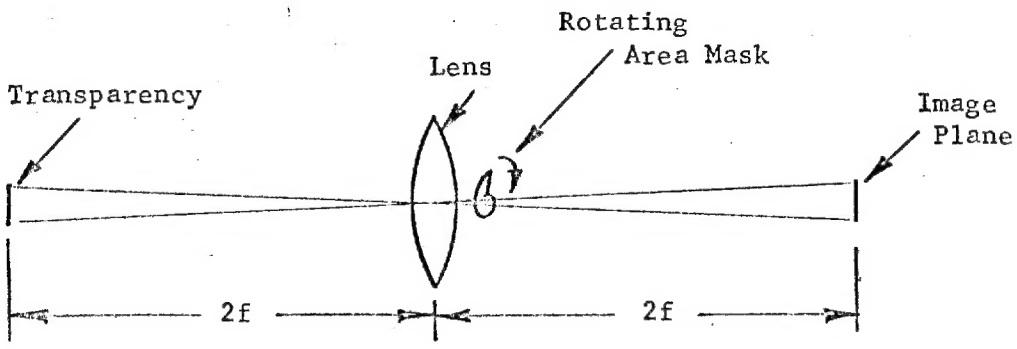

Figure 3. Modified Copy System